

# Data Assimilation and Observing Systems Working Group Report to the WWRP Scientific Steering Committee, WMO, Geneva (November 2015)

(Submitted by DAOS members and co-chairs Tom Hamill and Carla Cardinali)

## 1. DAOS terms of reference

The Data Assimilation and Observing Systems (DAOS) working group (WG) will provide guidance to the WWRP on international efforts to optimise the use of the current WMO Global Observing System (GOS). It will also provide guidance on which data assimilation methods may provide the highest-quality analysis products possible from the GOS. Through these activities, the DAOS-WG will facilitate the development of advanced numerical weather prediction (NWP) capabilities, especially to improve high-impact weather forecasts. DAOS will be primarily concerned with data assimilation and observing system issues from the convective scale to planetary scales and for forecasts with time ranges of hours to weeks. To achieve its mission, the DAOS WG will:

- a. Provide community consensus guidance on data assimilation issues, including the development of advanced methods for data assimilation.
- b. Promote research activities that will lead to a better use of existing observations and that will objectively quantify the impact of current and future observation for NWP.
- c. Assist WWRP projects and other WMO working groups in achieving their scientific objectives by providing expert advice on the use of observations and data assimilation techniques.
- d. Organize and provide the scientific steering committee for the WMO Data Assimilation Symposium, which is to be held approximately every 4 years.

## 2. Key highlights of DAOS activities in the last year.

- a. **Book chapters.** DAOS members contributed to several chapters of the recent WWRP OSC book, available [here](#).
- b. **8th DAOS working group meeting, Beijing, China, 27-28 October 2015.** The China Meteorological Administration (CMA) hosted our eighth meeting, where we discussed how to facilitate collaborations with CMA. More from this meeting in other key highlights below. See Annex A for actions from meeting.
- c. **Future meetings.** The next DAOS meeting will be in Exeter, England, 25-27 April 2016. Later on the 27th to the 29th will be the HIWeather meeting. For more DAOS-related meetings, see section 4 below. There was also discussion as to whether a workshop on convective-scale data assimilation was needed. It was noted that there is a parallel international yearly symposium on data assimilation sponsored by the German Weather Service (DWD), and they typically give this topic prominence in their meeting. Additionally, the US hosts a related ensemble Kalman filter workshop every two years. Finally, with the next DAOS meeting being coincident with HIWeather (April 2016 in Exeter, UK), there will be further opportunities to discuss mutual interests related to convective-scale assimilation there.
- d. **Forecast sensitivity to observations and observation database.** Previous DAOS member Ron Gelaro has developed a set of recommendations for terminology to be used in studies related to the Forward Sensitivity of Observation Impact (FSOI). Gelaro will either publish this as a standalone or incorporate this into a (DAOS-sponsored) review paper comparing different methodologies and different centres' estimated impacts. There still is active development and intercomparison of

adjoint-based and ensemble-based methodologies for estimating observation impact, including use of alternative norms for measuring the impact. Intercomparisons involving current and past DAOS members are in the works, and this will be discussed further at the upcoming May 2016 WMO Observation Impact meeting in Shanghai. Members also discussed the joint collaboration on setting up community software for saving observations and associated statistics (observation minus forecast, analysis minus forecast, QC information, bias correction, etc.).

- e. **Discussions of the scientific problems associated with coupled data assimilation.** In preparation for a possible 2016 DAOS workshop on coupled data assimilation, we discussed anticipated issues that should become a focus of the meeting. Most ocean-atmosphere data assimilation to date has been “weakly coupled,” i.e., the background forecasts are integrated with a coupled model but the assimilations are performed separately. A primary challenge with both land-atmosphere and ocean-atmosphere coupled data assimilation is whether the cross covariances between the state components will be realistic. A recent article on land-surface model (LSM) comparisons with flux observations ([Best et al. 2015](#)) highlighted the challenges and sub-standard performance of current-generation LSMs, indicating that there is the potential for biased covariance information between state components. That said, by developing coupled data assimilation methods, we are likely to learn at a faster rate about the underlying model deficiencies, so promoting the development of coupled DA methods is a priority for DAOS.
- f. **Reviews of observing systems.** More aircraft-based “AMDAR” observations are becoming available; currently there are more than 750K per day. Water-vapor measurements via GNSS zenith total delay and wind profiler information are growing as well, especially in Europe. Given the relative paucity of data over the oceans and the substantial positive impact from more and better data, [WMO and DAOS encourages members to continue and increase participation in JCOMM](#) (the Joint Technical Commission for Oceanography and Marine Meteorology). Two potential contributions to this are a NOAA proposal to upgrade barometers on drifters, and plans to increase automation of observations onboard ships. [DAOS highlights a potential major problem with weather radars, the increasing use of S- and C-Bands for telecommunications. See here for more.](#) As to satellite observing systems, though there still is concern about the US JPSS polar-orbiting weather satellite not being ready for use by the time the current one dies; however, there is hope and expectation that satellites from other countries, e.g., FY-3 from China, will provide complementary data. Europe plans to launch a satellite with the AEOLUS Doppler wind lidar system in 2016, which will provide a new and potentially very useful source of wind information. There are now atmospheric motion vectors derived from a wide variety of satellites, % (??) U. Wisconsin; by 2016 they will have reprocessed much past data to create these data sets for reanalyses. An international constellation of GPM (Global Precipitation Mission) satellites is now nearly complete (missing JPSS) that will provide near-complete, 3-hourly estimates of precipitation amount. Data is available via <http://pps.gsfc.nasa.gov>.
- g. **Reviews of assimilation methodologies.** Combinations of ensemble and variational techniques, e.g., 4D-En-Var are becoming more common operationally. There still are concerns about the ability of a finite ensemble to provide accurate estimates of flow-dependent covariances due to sampling issues and the challenges of applying localization techniques in four dimensions. Regional data assimilation is somewhat behind global in adopting 4D-En-Var. Major frontiers in assimilation methodologies continues to include methods for incorporating satellite data in cloudy regions, dealing with position errors in data assimilation (e.g., field alignment), and coupled assimilation techniques.
- h. **Greenhouse-gas assimilation.** The observation network for GHGs continues to improve, e.g., the OCO-2 (Orbiting Carbon Observatory; launched July 2014), and new ground based sites, e.g., 23 in Canada and 95 in Europe. The OCO-2 launch has spurred the development of near real-time

systems, though for latency to be comparable to regular NWP data assimilation systems, observations will need to be made available much more rapidly. Another big challenge is obtaining an accurate estimate of biospheric fluxes in near real time; these fluxes have been found to be critical to providing quality forecast products.

### 3. Relationships with other working groups, projects, and international initiatives.

- a. **Polar Prediction Project.** DAOS seeks to contribute to the PPP by: (a) promoting research into polar DA; (b) advising in the conduct of observing system experiments (e.g. the value of surface buoy data), and (c) advising in the conduct of selected OSSEs, e.g. what is the optimal deployment of observational equipment for the YOPP? In previous discussions with PPP members, DAOS noted that drift buoys have been at the top of the list of impact per observing system unit cost and should be supported by PPP and DAOS. The augmentation of the ARGO floats to provide surface-pressure measurements would also be extremely valuable.
- b. **High Impact Weather Project.** Examples of challenges and activities relevant to both HIWeather and DAOS were discussed. There is mutual interest in new observing strategies relevant to HIWeather local-weather concerns, including remote sensing, crowdsourced weather data, and high density, inexpensive networks such as cellular phone pressure data. Facilitating research into frequent (e.g., hourly) initialization of high-resolution regional models is of mutual research interest. Further challenges include methods of treating non-linearity of complex processes in data assimilation; assimilating observations continuously in time; and the simultaneous high-quality estimation of the state at large and local scales of interest. Possible activities to address these challenges include: (1) facilitating demonstrations of the impact of novel high-resolution, four-dimensional observing capabilities, for example of surface data and all phases of precipitation (2) facilitating the development of new nowcasting techniques, blending in forecast information from rapid-update data assimilation and NWP systems. (3) facilitating assessments of model error in data assimilation and ensemble forecasts (perhaps in collaboration with other working groups such as PDEF); (4) facilitating inter-comparison studies of multi-scale, coupled data assimilation for selected cases such as FDPs. (5) promoting the development of tools to assess the sensitivity of hazard forecasts to observational inputs.
- c. **Subseasonal to Seasonal Project.** DAOS and S2S agreed the following research areas were of mutual importance: (a) coupled data assimilation and its impacts on S2S forecasts (more important), including potentially a jointly sponsored workshop, and (b) quantifying impacts of improvements in the observing system on subseasonal forecasts (less important), and (c) identifying cases (thought experiments) where coupled data assimilation and forecasts would have a strong role at S2S timescales, e.g., perhaps MJO related. See Annex B for more.
- d. **Working Group for Numerical Experimentation.** WGNE leads shared their perspective on how DAOS could serve other WMO projects. These included: (a) YOPP and PPP: observation strategies for model development, data denial observing system experiments in polar regions, and quantifying analysis uncertainties in polar regions. (b) WGNE - DAOS mutual interests: coordination of activities on reanalyses, common observational databases, and coupled data assimilation. (c) DAOS, WGNE, and PDEF. A possible jointly supported workshop on stochastic parameterization, possibly supporting the upcoming 11-14 April 2016 ECMWF workshop on representation of model uncertainties. ECMWF interest in this co-sponsorship has been lukewarm, for they intend this workshop to more narrowly address ECMWF system development concerns. (d) DAOS and WGNE/Transpose-AMIP: WGNE notes that much could be learned from testing of coupled systems in data assimilation mode.

- e. **Other.** DAOS leads have initiated contact with WCRP leads about other areas of mutual interest beyond S2S; we await reply. DAOS leads are currently exploring areas of mutual interest with the GAW Scientific Advisory Group on Aerosols as well as of the WMO Sand and Dust Storm Warning and Assessment System (SDS-WAS) Steering Committee. DAOS has yet to reach out to [GURME](#). A report on HYMEX was presented at the 2015 DAOS meeting; see minutes for details on that.

#### 4. Planning for next year.

In addition to continuing DAOS advisory activities with other WMO working groups and projects, DAOS main activities in the next year will include:

- a. A potential 2016 international workshop on coupled data assimilation, potentially co-sponsored by S2S and/or WGNE. DAOS members have been in contact with S2S leads to identify a suitable venue and host organization for such a workshop. We note that DAOS was interested in co-hosting a workshop with ECMWF, but that they already have a fully booked calendar for next year.
- b. Participation in the 2016 Shanghai International Workshop on Observation Impact. DAOS co-lead Carla Cardinali is on the organizing committee.
- c. Preparations for the eventual 2017 quadrennial WMO International Symposium on Data Assimilation.

#### 5. Membership and meeting plans.

- a. **Current DAOS members.** Tom Hamill, NOAA (co-chair), Carla Cardinali, ECMWF (co-chair). Bin Wang (Institute of Atmospheric Physics / CAS), Nadia Fourrie (Meteo France), Sharan Majumdar (University of Miami, US), Stefan Klink (DWD), Chris Velden (U Wisconsin, US), Daryl Kleist (U Maryland, US), Mikhail Tsyrlunikov (Roshydromet), Saroja Polavarapu (Environment Canada), Mark Buehner (Canadian Meteorological Centre).
- b. **Changes in DAOS membership.** Hamill, Cardinali, Velden, and Tsyrlunikov will reach the 8-year point of DAOS service in Nov 2016. Cardinali is expected to continue to serve as co-chair until 2018. Hamill, Velden, and Tsyrlunikov will age off the committee in Nov 2016. A new co-chair and new members will be solicited, and we welcome SSC suggestions. DAOS notes prior interest from the WWRP SSC in finding a member from S. America, and we will need new experts with in-situ and satellite-observation experience in particular.
- c. **Meeting plans and requests for support:** Per discussion above, the major DAOS focus is on the potential 2016 meeting on coupled assimilation, the 2016 Observation Impact Workshop (Shanghai) and the 2017 international symposium. Collaborations between working groups in 2016 will be facilitated by the groups all meeting in Exeter in April 2016. Thereafter, PDEF and DAOS at the least would like to have WMO funding to permit one member to attend each other's meetings, and pending funding a DAOS member attending PPP and S2S would be desirable.

#### Annex A: Actions from 8<sup>th</sup> DAOS WG Meeting, Beijing

Action 8.1: Contact former DAOS member Ron Gelaro (NASA) to suggest submission of an MWR expedited contribution on the recommended terminology for forecast sensitivity to observations (Ron,

Carla, Rolf). This note should then be tabled at the next WMO CBS Workshop on the impact of observations. **Status: complete.** Awaiting response from Ron.

Action 8.2: Solicitation of proposals to host the next WMO Symposium.

- a. DAOS WG members to contact potential hosts for the next symposium to gauge their interest in eventually submitting a proposal to host (all, especially Daryl Kleist regarding Eugenia Kalnay/Argentina interest, Jiandong Gong of CMA regarding China, Nadia Fourrie regarding France, Carla Cardinali regarding Andrew Lorenc/Met Office/England, and Tom Hamill regarding Japan and Brazil). Deadline: 1 Jan 2016.
- b. Daryl Kleist to share the successful proposal from the 2013 DC symposium as well as other information on costs with other DAOS members. Deadline: 7 December 2015.
- c. Tom Hamill and Carla Cardinali to contact scientists and potential host organizations as determined from (a) above to determine if they are willing to submit a full proposal. Hamill and Cardinali will indicate what information will be requested in the proposal, along with a due date for submission of the proposal. Deadline: 1 April 2016.

Action 8.3: DAOS to co-ordinate timing of the future WMO DA symposium with the International DA meeting. (Roland Potthast, DWD is the current German symposium representative). See also Action 8.8 below.

Action 8.4. Exploring the need for a coupled DA workshop. WMO DAOS members will investigate possible cities, venues, and partners for an international workshop on coupled data assimilation in the summer-fall 2016 timeframe. Carla Cardinali, Daryl Kleist, and Saroja Polavarapu in particular are requested to provide feedback in England, the US, and Canada respectively. Deadline for initial feedback is 7 December 2015. Further actions may follow as a result of this feedback.

Actions 8.5 Survey of possible collaborative activities on OSSEs.

- a. DAOS members to review Sharan Majumdar's draft list of potential questions to ask operational centres and other organizations with respect to collaboration on observing-system simulation experiments (OSSEs), and provide feedback and suggestions of other possible questions to Sharan. Members are also requested to provide e-mail addresses for staff that they think the questions should be sent to. Deadline is 23 November 2015[TH1] .
- b. Sharan Majumdar to distribute the final list of questions to relevant staff identified in (a) above, with the intent of receiving feedback no later than 30 January 2016. Deadline: 7 December 2015.
- c. Sharan to present results of the survey at the next DAOS meeting.

Actions 8.6: Preparation for the 2015 WMO/WWRP Science Steering Committee meeting.

- a. Tom Hamill and Carla Cardinali to respond to data call by Paolo Ruti (16 Oct 2015 email) requesting information for WWRP SSC meeting, including: report on working group (4 pages or less); a presentation covering material in the working group report; provide advice with respect to RDPs (research demonstration projects) and FDPs (forecast demonstration projects) that the working group is overseeing. Deadline 7 November 2015.
- b. Tom Hamill and Carla Cardinali to respond to the 23 September 2015 e-mail from Paolo Ruti to provide input to the WWRP Implementation plan and planning matrix. Deadline: 6 Nov 2015.

Action 8.7: Sharan Majumdar to contact leads of WWRP Mesoscale Weather Forecasting Research and Nowcast Research working groups regarding whether very rapidly updating data assimilation methods (less

than hourly) should be a topic to be covered by DAOS as well as by their working groups. Deadline 7 December 2015.

Actions 8.8. Gauging whether a workshop on convective-scale data assimilation organized or co-organized by WMO is needed. All deadlines are 6 Dec 2015.

a. Daryl Kleist to contact Roland Potthast, organizer of another international symposium on data assimilation, to determine whether convective-scale initialization interests of DAOS will be suitably covered by this parallel international effort. See also action 8.3 above.

b. Tom Hamill to monitor the yearly US EnKF workshops (Fuqing Zhang, Penn State) to determine whether these will continue to discuss convective-scale data assimilation in depth sought by DAOS.

c. Sharan Majumdar to contact HIWeather lead Brian Golding to discuss mutual interests on convective-scale data assimilation and determine whether DAOS should consider the next WG meeting to be coincident with HIWeather.

Action 8.9. DAOS members to circulate WMO Polar Prediction Project (PPP) information (available at <http://www.polarprediction.net/about-ppp.html>) to potentially interested data assimilation experts in their own countries. Also, DAOS members will encourage them to share this more widely and have relevant staff contact PPP leads if any are interested in collaborative activities. It was noted that PPP seeks expertise on polar observing systems, the coordination of additional observations, the refinement of methods unique to polar systems, characterization of observation and background uncertainty (including model error) relevant to polar concerns, possible characterization of radiative transfer and retrieval errors in polar regions, verification in polar regions, and observation sampling strategies. Deadline: 6 December 2015.

Action 8.10 Tom Hamill and Carla Cardinali to initiate coordination with WMO Aerosol Science Advisory group to determine if additional collaborative activities are warranted between the two groups. Deadline: 1 March 2016.

Action 8.11. Following a suggested action from the 2014 WWRP Science Steering Committee, DAOS leads to initiate contact with key scientists in WCRP to discuss research areas of mutual concern. Deadline: 7 December 2015.

Action 8.12. Following a recommendation of the 2014 WWRP Science Steering Committee, DAOS leads will explore whether there are colleagues in S. America that may be suitable as replacements for current DAOS members when they age off the committee. DAOS members are encouraged to make suggestions. Deadline: 7 December 2015.

Action 8.13. [from 2014 WWRP Science Steering Committee] DAOS and PDEF chairs to prioritize coupling issues and respond at the next WWRP Science Steering Committee.

DAOS and PDEF leads have discussed this. It was unclear whether "coupling" referred to the coupling of the working groups or coupling of state components of the environment. Regarding the former, DAOS and PDEF have mutual interest in the development of ensembles and methods for treating model uncertainty in ensembles. Pending available funding from the WMO, we have agreed that it would be desirable to try to have one person from each group attend the other group's meetings. Since there often are some members of a working group who cannot attend any given meeting, their absence might provide the funding for a person from the other working group to attend.

Regarding a prioritization of coupling state components, this is more difficult to do in an objective fashion. Improved coupling of the sea ice and atmosphere will be of great relevance to PPP, but its impact is more geographically limited than the impact of coupling the ocean and atmosphere or land and atmosphere. Hence, our kneejerk reaction is that the coupling of ocean

and land with the atmosphere are the biggest global priorities, but not necessarily the biggest regional priorities.

It is noted that the land-surface community is currently re-evaluating the use of very complex dynamical land-surface models for estimating fluxes of sensible and latent heat to and from the atmosphere; see <http://journals.ametsoc.org/doi/abs/10.1175/JHM-D-14-0158.1> . The success of coupled land-atmosphere modeling and coupled data assimilation are likely dependent on making progress on improving the methodologies in land-surface models.

Action 8.14: Each member to provide 1-2 paragraphs on their presentations at the meeting to DAOS co-chairs. Due 9 November 2015.

Action 8.15: Daryl Kleist will provide link for MWR special collection from previous THORPEX symposium to WMO staff (Nathalie Tournier) to put on DAOS web page . Due 9 November 2015.

Action 8.16: Members to suggest to DAOS leads other potential WG members with relevant coupled DA expertise as well as non-satellite observations. Deadline 7 December 2015. GODAE 2013 Ocean View [documents](#) might be good resource for this.

Action 8.17: DAOS leads to review length of tenure of existing DAOS members with WMO leadership, and identify people that need to age off the committee.

Action 8.18: DAOS members to provide names of staff at their organizations to DAOS leads who may be interested in cooperation on building Observation Database software (i.e., a database that not only stores observation data, but also bias-correction information, O-F, O-A, etc.). Deadline 7 December 2015.

Action 8.19: Mikhail Tsyrlnikov (and others if they desire) are encouraged to develop a list of people from related disciplines who may be interested in attending the WMO DA symposium.

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[TH1]Daryl Kleist noted that we may wish to do after-the-fact queries on OSSEs; did operational centres and associated organizations (e.g. EUMETSAT, NESDIS) think previous OSSEs were valuable. Related, perhaps we should formulate a question on whether previous OSSEs were valuable?

**Distinctions and synergies of DAOS and PDEF interests  
in Coupled Modeling and Data Assimilation**

In the Fall of 2015, the DAOS co-chairs (Carla Cardinali, Tom Hamill) and PDEF co-chairs (Craig Bishop, Richard Swinbank) discussed their working groups' mutual interests in coupled modelling, ensemble prediction, and data assimilation. A high degree of overlapping interest was found in the areas of ensemble initialization and model-error representation. However, DAOS and PDEF serve differing user groups and hence, it was agreed that across all forecast-lead-times (including those pertaining to coupled modelling) DAOS should address issues of concern to those primarily interested in data assimilation and observing systems while PDEF should address issues of concern to those primarily interested in predictability, dynamics and ensemble forecasting.

In the area of coupled modelling, there was general agreement that the ocean-atmosphere coupling and land-atmosphere problem should receive the highest priority initially. Through interaction with the PPP, we also hope to address aspects of ice-ocean and ice-atmosphere coupling. Coupled modelling systems which realistically represent interactions of the atmosphere with land and ocean are important for extended-range prediction, which is particularly relevant to supporting the subseasonal to seasonal prediction (S2S) project. Realistic representation of interactions with the cryosphere is also critical for prediction at high latitudes – the focus of the polar prediction project (PPP). Despite strong overlaps in the areas of ensemble forecasting and model error, PDEF will have a much stronger focus on increasing understanding of the dynamics of the coupled system than DAOS, while DAOS will pay more attention to improving observing networks for the coupled system and issues related to the realism of coupled uncertainty estimates in the short-range background forecasts. Weakly coupled DA is the most practical approach to coupled atmosphere-ocean assimilation in the short term, while the development of (more) strongly coupled DA systems requires a better understanding of coupled uncertainty estimates. We anticipate that experience with coupling the atmosphere with both ocean and land will help with addressing other coupling problems, such as ice-ocean-atmosphere.

Both PDEF and DAOS working groups have a common interest in the treatment of model uncertainties, as part of the DA cycling and in ensemble forecast models, respectively. Diagnostic techniques in the context of DA cycling could potentially be very helpful for informing us about how best to represent model uncertainties using stochastic physics methods. Participation of some DAOS members in the proposed joint ECMWF/PDEF workshop on model uncertainty will be very helpful.

To help ensure that DAOS and PDEF work synergistically on these issues, it was agreed that a representative from PDEF should be invited to attend future meetings and workshops of the DAOS working group, and vice versa.

Craig Bishop, Carla Cardinali, Tom Hamill and Richard Swinbank